

**An Advanced Fracture Characterization and Well Path Navigation System
for Effective Re-Development and Enhancement of Ultimate Recovery from
the Complex Monterey Reservoir of South Ellwood Field, Offshore
California**

Quarterly Technical Progress Report

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Abstract

Venoco Inc, intends to re-develop the Monterey Formation, a Class III basin reservoir, at South Ellwood Field, Offshore Santa Barbara, California.

Well productivity in this field varies significantly. Cumulative Monterey production for individual wells has ranged from 260 STB to 8,700,000 STB. Productivity is primarily affected by how well the well path connects with the local fracture system and the degree of aquifer support. Cumulative oil recovery to date is a small percentage of the original oil in place. To embark upon successful re-development and to optimize reservoir management, Venoco intends to investigate, map and characterize field fracture patterns and the reservoir conduit system. State of the art borehole imaging technologies including FMI, dipole sonic and cross-well seismic, interference tests and production logs will be employed to characterize fractures and micro faults. These data along with the existing database will be used for construction of a novel geologic model of the fracture network. Development of an innovative fracture network reservoir simulator is proposed to monitor and manage the aquifer's role in pressure maintenance and water production. The new fracture simulation model will be used for both planning optimal paths for new wells and improving ultimate recovery.

In the second phase of this project, the model will be used for the design of a pilot program for downhole water re-injection into the aquifer simultaneously with oil production. Downhole water separation units attached to electric submersible pumps will be used to minimize surface fluid handling thereby improving recoveries per well and field economics while maintaining aquifer support.

In cooperation with the DOE, results of the field studies as well as the new models developed and the fracture database will be shared with other operators. Numerous fields producing from the Monterey and analogous fractured reservoirs both onshore and offshore will benefit from the methodologies developed in this project.

This report presents a summary of all technical work conducted during the fourth quarter of Budget Period I.

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Introduction

The Field Demonstration site for this Class III (basin clastic) Program Proposal is the South Ellwood Field located offshore California. The Monterey Formation is the main producing unit in the South Ellwood Field and consists of fractured chert, porcelanite, dolomite, and siliceous limestone interbedded with organic mudstone. This reservoir has an average thickness of 1,000 feet, and lies at subsea depths of approximately -3,500' to -5,000'.

Venoco and USC jointly submitted an application to conduct a DOE co-operative investigation of the Monterey formation at South Ellwood in June 2000. The DOE granted this application in July 2000.

Executive Summary

Venoco and USC prepared a proposal for a DOE sponsored joint investigation of the fractured Monterey formation. It was agreed that Venoco would construct the geologic model for the field and gather new reservoir data as appropriate. USC would then develop a simulation model that would be used to optimize future hydrocarbon recovery. Joint Venoco-USC teams were established to manage the flow of data and insure that Venoco and USC activities remained synchronized. A co-operative agreement was signed with the DOE on July 31, 2000.

During the fourth quarter the emphasis was on the acquisition of new data. Static pressures were obtained on several long-term shut-in wells at South Ellwood. The central area of the Monterey appears to have declined from an initial pressure of 1800 psi to 1300 psi currently. There was no evidence of any pressure support other than from the area to the East of block PRC 3242. This pressure support may represent influx from the Monterey crestal area that is known to exist on the former 308 lease.

A project to reprocess all the available dipmeter data was completed. It was thought that the caliper traces from these logs might reveal borehole breakout effects and probable fracture trends. Unfortunately, all the wells examined were highly deviated and the drag effects created by the directional tools masked any breakouts that could have developed. It is expected that the imaging tools that will be run on future wells will be able to distinguish fractures directly.

In conjunction with the PTTC, Venoco hosted a workshop and field trip on the Monterey formation. USC and Venoco gave presentations on South Ellwood summarizing the latest information from the DOE project.

Task I. Database

A temporary web site was created to store the associated files for the database. A web site development software NET OBJECTS was used for the site design.

Task II: New Data

We measured Bottom hole pressure in six long term shut-in wells:- 3120-4, 3120-6-2, 3242-7-1, 3242-10-1, 3242-14 and 3242-17. Data from four of the wells shows that the reservoir pressure ranges from 1260-1320 psi at datum. There is no evidence for aquifer support from the northern boundary fault. A higher than normal pressure in 3242-7-1 suggests that influx from the former 308 lease is occurring.

Task III-Geological/Reservoir

Schlumberger completed processing dipmeters for the 11 deviated South Ellwood wells. The breakouts appear to strongly correlate with borehole trajectory. The four arm calipers could not separate the borehole deviation effects from the borehole breakout. Retrieved digital dipmeter data for two vertical exploration wells.

Pipeline Fracture Model Simulator

Made simulation runs comparing a conventional dual porosity model using the CMG simulation package with the new pipeline network model.

The results of the base case are shown in Fig. 1, where (a)-(c) are the water saturation distributions calculated by CMG after starting production 100 days, 300 days and 1000 days, respectively, and (d)-(e) are the corresponding PNM results. In general, the two models provide almost the same (both shape and saturation values) coning front of the bottom water. However, after 300 days, the difference between the two models becomes noticeable, although still not large. The PNM has a much more extensive zone affected by water coning. This is most evident in the results at 1000 days. At first, dispersion effects were suspected as being the cause of this difference. However, we verified that the differences arose from the completely different fluid transport mechanism envisaged in the PNM.

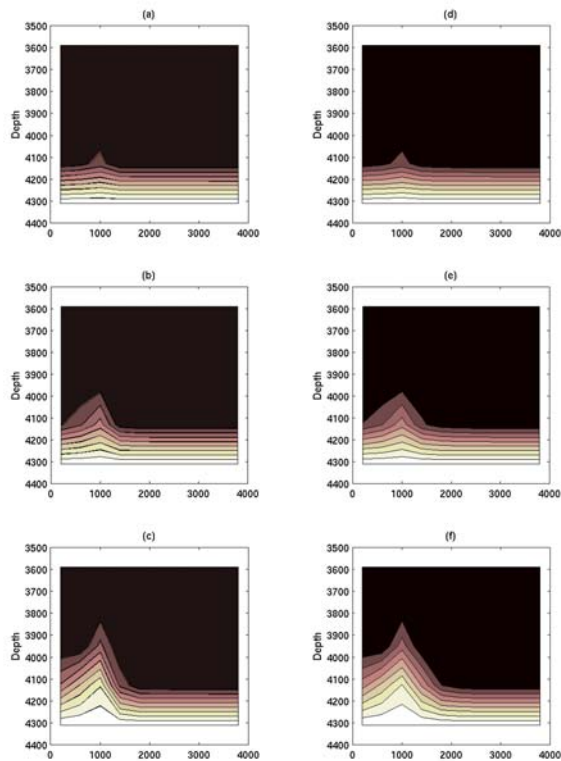


Figure 1. Comparison of saturation distributions obtained from CMG simulator and PNM model. Base case: (a) CMG results, $t=100$ days; (b) CMG results, $t=300$ days; (c) CMG results, $t=1000$ days; (d) PNM results, $t=100$ days; (e) PNM results, $t=300$ days; (f) PNM results, $t=1000$ days.

Task IV-Stimulation

None

Task V- Reservoir Management

Project review meetings were held on a monthly basis in Santa Barbara. Progress reports from various individuals were reviewed. Individuals working on the project during this quarter included:

Database:

Katie Boerger (USC), Ursula Wiley (USC), Kim Halbert (Venoco) and Tim Rathman (Venoco), Chris Knight (Venoco),. I, Ershaghi (USC)

Reservoir Studies:

I. Ershaghi (USC), Lang Zhang (USC), A. Zahedi (USC), Ursula Wiley (USC), Juan Anguiani (USC), Steve Horner (Venoco)

Geological Modeling

Mike Wracher (Venoco), Karen Christensen (Venoco)

Geophysical Modeling

Karen Christensen (Venoco)

Project Management:

Karen Christensen (Venoco) and I. Ershaghi (USC)

Task VI--Tech Transfer

4/10/2001

Presentation to GSA/AAPG. South Ellwood Field, Santa Barbara Channel, California: Is a Normal Fault Always Normal? (Karen Christensen)

4/10/2001

Presentation to GSA/AAPG. Three Dimensional interpretation of the Sockeye Structure: Santa Barbara Channel, California (Mike Wracher)

6/20-21/2001

Organized a workshop and a field trip on geological complexities of the Monterey Formation with the West Coast PTTC. Karen Christensen and Iraj Ershagi presented talks on geology and reservoir engineering aspects of this formation.

6/13/2001

Presentation to Pacific Section SEG. New 3D Seismic Processing Data Results from the Santa Barbara Channel, Karen Christensen.

Conclusions

Static bottom hole pressure data has proven very useful in determining the likely source of pressure support for South Ellwood field. The central area of the field has been depleted from an initial pressure of 1800 psi to 1300 psi with very little evidence for aquifer support. On the other hand influx appears to be occurring from the undeveloped crestal portion of the field on the former 308 lease.

Use of the four arm caliper data from the original dipmeter logs to predict minimum stress orientation did not prove successful. All the wells were highly deviated and the caliper tool could not separate any borehole breakout from the hole disturbance caused by the direction drilling tools.